Bassian bats in the Eyrean sub-region? Preliminary acoustic data from the Bogan and Macquarie Rivers in semi-arid NSW

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ABSTRACT

We conducted acoustic surveys of insectivorous bat fauna in riparian areas along the Macquarie and Bogan River systems in the wheatbelt of semi-arid central-western New South Wales, Australia. In surveys of 10 sites we detected 11 species and two species groups of bats in eight genera. Four species, Chocolate Wattled Bat *Chalinolobus morio*, Large-footed Myotis *Myotis macropus*, Large Forest Bat *Vespadelus darlingtoni* and Southern Forest Bat *V. regulus*, are predominantly Bassian (chiefly coastal) in their recorded distributions but were detected in the semi-arid Eyrean sub-region on two rivers in vegetation dominated by River Red Gum *Eucalyptus camaldulensis*. The findings of this study highlight the need for further research to assess the importance of riparian corridors as habitat for insectivorous bats in semi-arid New South Wales.

Key words: semi-arid woodland, river red gum, *Eucalyptus camaldulensis*, microchiropteran bats, distribution, threatened species

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Introduction

Vegetation of inland water courses across much of semi-arid Australia (within the Eyrean biogeographical sub-region *sensu* Spencer 1896) is typically dominated by River Red Gum *Eucalyptus camaldulensis* (Dehnh.: Metcalfe *et al.* 2003). In landscapes that are highly modified by clearing for agricultural and river regulation (Sivertsen 1993; Bedward *et al.* 2007), riparian vegetation is likely to represent important habitat for many species of birds (Williams 1994; Catterall *et al.* 2001; Martin *et al.* 2006) and insectivorous bats (Lumsden and Bennett 1995; Grindal *et al.* 1999; Young and Ford 2000; Monadjem and Reside 2008). However, our knowledge of fauna using riparian areas is limited for large areas of inland Australia.

Microchiropteran bat species represent over 25 % of Australia's native mammal fauna and yet they remain poorly understood. The inland woodlands of eastern Australia are home to at least 16 species (Churchill 2008; van Dyck and Strahan 2008) of which 13 are expected to occur in the central wheatbelt of New South Wales (NSW) (Churchill 2008). Although some studies have surveyed the bat fauna of eastern Australian inland woodlands (Lumsden and Bennett 1995; Law and Anderson 1999; Law *et al.* 2011), many areas have received scant attention. Consequently, the bat fauna of semi-arid woodlands in eastern Australia remains poorly documented (Churchill 2008) and it is possible that species' distributions extend beyond their current known ranges (Pennay *et al.* 2011). This may also include species known from the chiefly coastal, cool-humid Bassian (*sensu* Spencer 1896) biogeographical sub-region in south-eastern Australia. An understanding of the distribution of bat species across the highly modified landscapes of the semi-arid woodlands of Australia is an essential tool for conservation management decisions.

Eucalyptus camaldulensis-dominated woodlands can contain large numbers of hollow-bearing trees (Bennett *et al.* 1994; Rayner *et al.* 2011, in press) that may provide winter, maternal or daytime roosting sites for bats. In fact, *E. camaldulensis* has been identified as important roosting habitat for male (95.1 % of roosts; n=41) and female (100 %; n=51) Gould's Wattled Bats (*Chalinolobus gouldii* Gray) and female (80.8 %; n=78) Lesser Long-eared Bats (*Nyctophilus geoffroyi* Leach) in rural Victoria (Lumsden *et al.* 2002). Additionally, riparian vegetation serves as an edge that bats may use to assist with navigation while foraging (Limpens and Kapteyn 1991; Verboom and

Huitema 1997; Gonsalves *et al.* 2012), or may provide protection from predation since bats can be preyed upon while foraging in open pastures and fields (Estrada *et al.* 2004). Riparian areas are also known to have high insect abundance (Brigham and Fenton 1991; Whitaker *et al.* 2000; Fukui *et al.* 2006) which may serve to concentrate bat activity in semi-arid areas. Thus riparian areas are a logical starting place to survey bats and their species richness in an area that has had little survey work in the past (Law *et al.* 2011).

Our study aimed to document the insectivorous bat fauna of *E. camuldelensis*-dominated riparian vegetation within the semi-arid woodlands of the wheat-sheep belt of central-western NSW. Here, we report findings of acoustic surveys in riparian vegetation along the ephemeral Bogan River and the permanent Macquarie River, NSW.

Methods

Study area

The study area was on the western plains of NSW centred on 148°00' E 32°30' S and straddled four 1:100,000 mapsheets: Dandaloo (8433); Narromine (8533); Peak Hill (8532); and Tullamore (8432). It was within a 10,000 km^2-section of the wheat-sheep belt of central-western NSW and was west of the 300-m altitude contour along the Hervey Ranges and adjacent uplands (Fig. 1). The study area has a semi-arid climate with average annual rainfall of 527 mm (Narromine, >50-year mean, Bureau of Meteorology).

All sampling sites were in the riparian zones of the Bogan and Macquarie Rivers and within the *E. camaldulensis* Forests and Woodlands (R1) of Metcalfe *et al.* (2003).

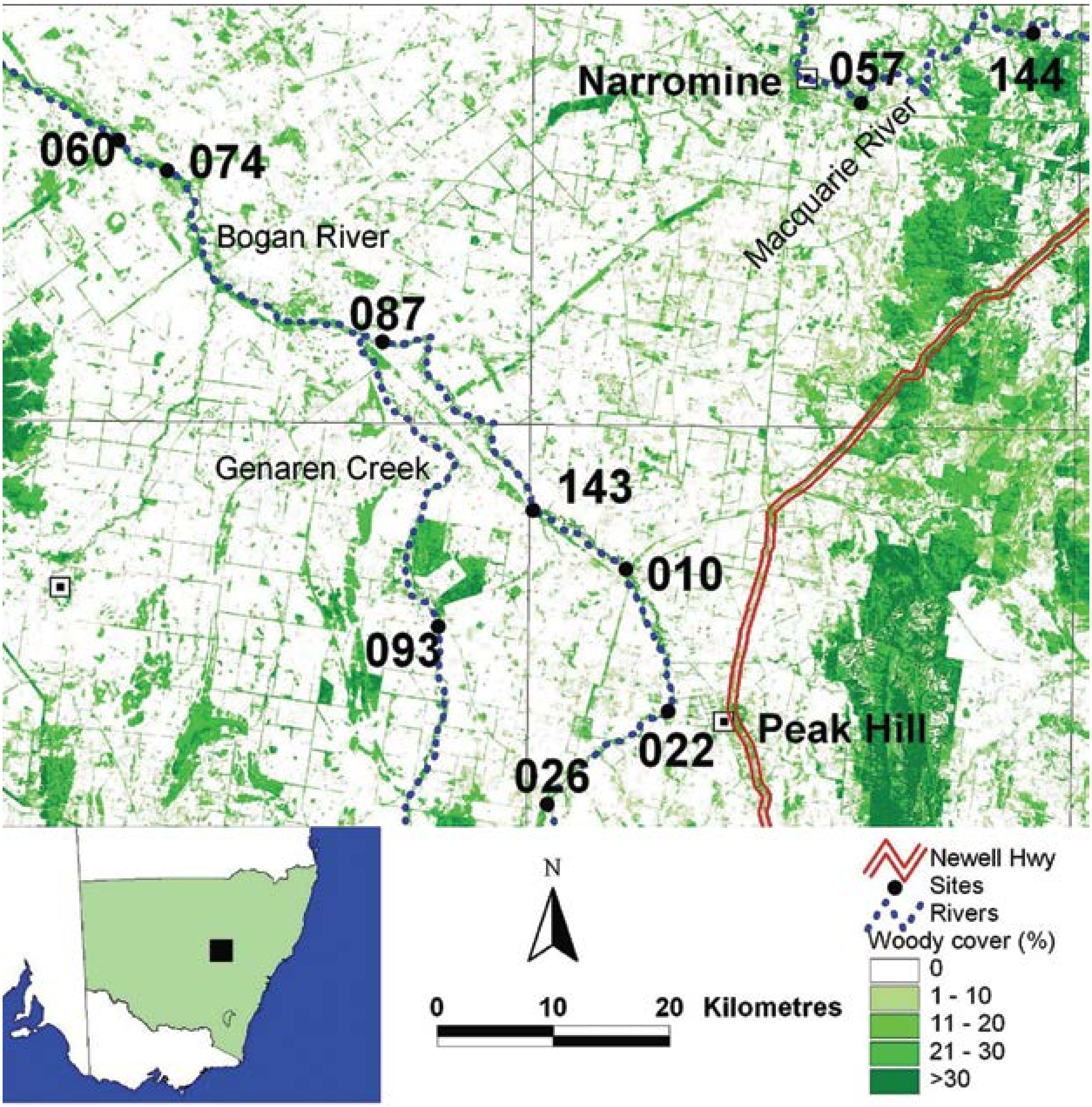

Figure 1. Distribution of sites along the Macquarie and Bogan Rivers in semi-arid NSW in relation to the distribution of remnant woody vegetation.

The vegetation canopy was dominated by *E. camaldulensis*, with some trees having diameters at breast height (DBH) >2 m (Rayner *et al.* in press), but there were also occasional individuals of Yellow Box *E. melliodora* (A. Cunn. Ex Schauer), Black Box *E. largiflorens* (F.Muell.) and Fuzzy Box *E. conica* (Deane and Maiden). Foliage cover of woody vegetation varied within and among the 1-ha sites. Sites had foliage cover ranging from 21 to 58% on the Bogan River and 33 to 39% on the Macquarie River. At the time of sampling, all sites had open grassy understoreys with variable forb cover and 90-100% of woody vegetation was attributable to *Eucalyptus* species. Areas surrounding all sites consisted of cropped or grazed agricultural lands with remnant *Eucalyptus*, *Callitris* or *Acacia* woodlands of the Plains vegetation type of Metcalfe *et al.* (2003) (Fig. 1).

Bat surveys

Acoustic surveys of bats were conducted at 10 sites (Fig. 1) during a summer period (11-14 December 2012) and an autumn period (19 – 22 March 2013). These sites were a subset of 1-ha sites surveyed for birds and tree hollows in complementary studies (Ellis and Taylor 2013; Rayner *et al.* in press). An Anabat detector (Titley Electronics, Ballina, Australia) mounted slightly above horizontal, 2.5 m above ground level on the trunk of a River Red Gum tree clear of any foliage was used at each site (Fig. 2). Detectors were set as close as possible to the centre of each 1-ha survey site with microphones directed towards the river channel. Detectors were operated from dusk until dawn.

Six sites were surveyed simultaneously for three consecutive nights in December 2012; two on the Macquarie River (sites 57 and 144: Fig. 1), three on the Bogan River (sites 10, 26 and 143) and one on a tributary of the Bogan River (Genaren Creek, site 93). Six sites were surveyed in March 2013 for 3-4 nights each; four new sites on the Bogan River (sites 22, 60, 74 and 87) and two re-surveyed sites (site 57 on the Macquarie R. and site 143 on the Bogan R.).

Conditions during the December 2012 sampling period were hot and dry with mean (±SE) daily minima and maxima of 17.2 ± 0.5 °C and 34.1 ± 1.2 °C at Trangie (34 km north-west of study area) and 15.8 ± 0.4 °C and 32.9 ± 1.3 °C at Dubbo (41 km east of study area) (Bureau of Meteorology). No rainfall was recorded in Trangie or Dubbo during the December 2012 sampling period. During the March 2013 sampling period, temperatures were slightly cooler with mean (±SE) daily minima and maxima of 18.4 ± 1.8 °C and 28.6 ± 0.5 °C at Trangie and 15.4 ± 1.2 °C and 28.1 ± 0.6 °C at Dubbo. There was light rain during the March 2013 sampling period with a total of 13.8 mm and 7 mm recorded at Trangie and Dubbo respectively. The Macquarie River had permanent flowing water and the Bogan River had ephemeral pools at or adjacent to all sites during both sampling periods.

Anabat files were analysed at the end of each sampling period using Anascheme software (Adams *et al.* 2010) in association with a taxonomic key developed for the Murray-Darling basin (B. Law, unpublished data). Anabat files with fewer than three valid pulses (i.e., minimum of six data points and model quality of ≤ 0.9) were not analysed by AnaScheme. Because multiple bat species may call simultaneously, calls were assigned to a species only if >50 % of pulses within the sequence were attributed to that species and only passes with a minimum of three pulses classified to the same species were identified. All calls that could not be assigned to a bat taxon were not considered here. Since it is not possible to differentiate species in certain genera, the identification key grouped certain species. '*Nyctophilus* species' could include Gould's Long-eared Bats, *Nyctophilus gouldi* Tomes, Lesser Long-eared Bats, *N. geoffroyi*, and South-eastern Long-eared Bats, *N. corbeni* Parnaby; *N. geoffroyi* has been trapped in the study area and the other two species trapped nearby (M.V. Ellis, unpublished data). '*Mormopterus* species' could include calls from Eastern Freetail Bats, *Mormopterus* sp. 2, *Mormopterus* sp. 3 and *Mormopterus* sp. 4. Calls of *Nyctophilus* spp. and Large-footed Myotis (*Myotis macropus* Gould) are very similar to each other and are difficult to distinguish confidently using AnaScheme. Consequently, *M. macropus* was not in the identification key for the Murray-Darling basin (B. Law, unpublished data). Calls labelled as *Nyctophilus* spp. by AnaScheme were screened manually and identified as *M. macropus* if calls had a central kink around 47-50 kHz (Pennay *et al.* 2004). Similarly, calls of *Vespadelus darlingtoni* Allen

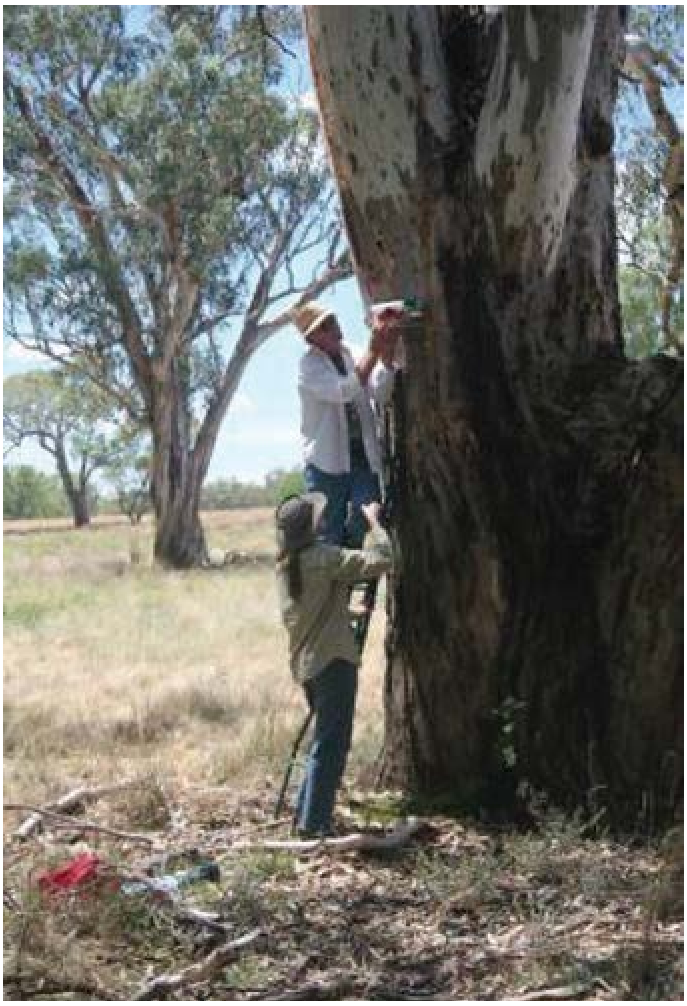

Figure 2. An Anabat detector being attached to the trunk of a River Red Gum.

and *V. vulturnus* are difficult to distinguish when the characteristic frequency lies within 44-46 kHz, while calls of *Chalinolobus morio* and *V. regulus* Thomas are difficult to differentiate when the characteristic frequency is 50-53 kHz (Pennay *et al.* 2004). Calls identified as *V. darlingtoni* and *C. morio* by AnaScheme were manually checked and if characteristic frequency was ≤ 43 kHz they were identified as *V. darlingtoni* or if alternating pulse shapes were apparent with every second pulse being steeper or shorter they were identified as *C. morio*.

Results

Across both sampling periods and all sites, 7 981 bat calls were recorded of which 3 157 were identified, representing 11 species and two species groups (Table 1). At least four of these species are considered to have distributions that are predominantly within the more coastal, Bassian sub-region (*C. morio*, *M. macropus*, *Vespadelus darlingtoni*, *V. regulus*: Figs. 3-6). In our study area these four species were either marginal to or beyond their known range (Figs. 3-6; Table 1; examples of frequency *versus* time graphs in Appendix 1). Ten species and two species groups were recorded at sites along the Macquarie River. Eight species and two species groups were recorded along the Bogan River (Table 1).

Chalinolobus gouldii, *V. darlingtoni* and *V. vulturnus* Thomas were recorded at all sites. Three threatened species were detected, *C. picatus* Gould and *M. macropus* on the Macquarie River and *Saccolaimus flaviventris* Peterson on the Bogan River (Table 1). *Scotorepens balstoni* Thomas, *Sc. greyii* Gray, *T. australis* Gray and the two species groups were detected on both rivers and at >75% of sites (Table 1). Three species detected at Macquarie River sites were not detected at the Bogan River sites and one species detected at the Bogan River was not detected at the Macquarie River (Table 1).

Discussion

Riparian *E. camuldulensis* vegetation along the Bogan and Macquarie Rivers supports a diverse range of bat taxa, representing 11 species and two species groups in three families (Emballonuridae, Molossidae and Vespertilionidae), providing further support to studies that have suggested that inland riparian areas are important habitats for bats in semi-arid landscapes (Lumsden and Bennett 1995; Law and Anderson 1999; Young and Ford 2000; Law *et al.* 2011). The spatial and temporal coverage of our acoustic sampling (≥ 3 nights at 10 sites) is likely to have detected most of the common species present in the riparian vegetation of our study area but we may have failed to detect rarer species (Skalak *et al.* 2012). For example, *V. baverstocki* may be present within the study area based on known distribution (Lumsden and Bennett 1995; Pennay *et al.* 2011).

Compared to surrounding plains and hills, riparian zones of the Bogan and Macquarie Rivers provide mesic conditions, not only by collecting local rainfall runoff, but by draining adjacent areas of the Great Dividing Range to the east. This allows the development of *E. camuldulensis* forest and woodlands along their banks with the growth of some trees to >2-m DBH (Rayner *et al.* in press). There is evidence that mesic corridors in Australia are used by birds to expand their distribution into drier areas (MacNally *et al.* 2000) and riparian corridors are apparently important for bat movements through the landscape elsewhere in the world (Lookingbill *et al.* 2010). Data about use of mesic corridors by bats in Australia are limited (Law and Anderson 1999) but Ellis *et al.* (1989) reported a population of *N. gouldi* hundreds of kilometres inland along the Macquarie River, a range extension into inland xeric landscapes. Although an important question for conservation managers, it was beyond the scope of our study to assess whether bat species were using the

Table 1. Occurrence of bat species at sites (see Fig. 1) in each sampling period and percentage of sites on the Bogan and Macquarie Rivers and overall in which each bat species was recorded.

	Bogan			Macquarie			
Species	sites December (n = 4)	sites March (n = 5)	% of sites (n = 8)	sites December (n=2)	sites March (n=1)	% of sites (n = 2)	% of all sites (n = 10)
Chalinolobus gouldi Gray	All	All	100	57, 144	57	100	100
C. morio Gray	--	--	0	144	--	50	10
**C. picatus* Gould	--	--	0	144	--	50	10
Mormopterus spp.	10,26,143	22,60,87,143	75	57, 144	57	100	80
Nyctophilus spp.	All	22,74,87	87.5	57, 144	57	100	90
**Myotis macropus* Gould	--	--	0	--	57	50	10
**Saccolaimus flaviventris* Peters	10,26,143	22,143	50	--	--	0	40
Scotorepens balstoni Thomas	All	60,74,87	87.5	57,144	57	100	90
Sc. greyii Gray	All	22,74,87,143	87.5	144	57	100	90
Tadarida australis Gray	All	22,74,143	75	144	57	100	80
Vespadelus darlingtoni Allen	All	All	100	144	57	100	100
V. regulus HF Thomas	26,143	--	25	57,144	57	100	40
V. vulturnus Thomas	All	All	100	57,144	57	100	100

* species listed under the *NSW Threatened Species Conservation Act 1995*

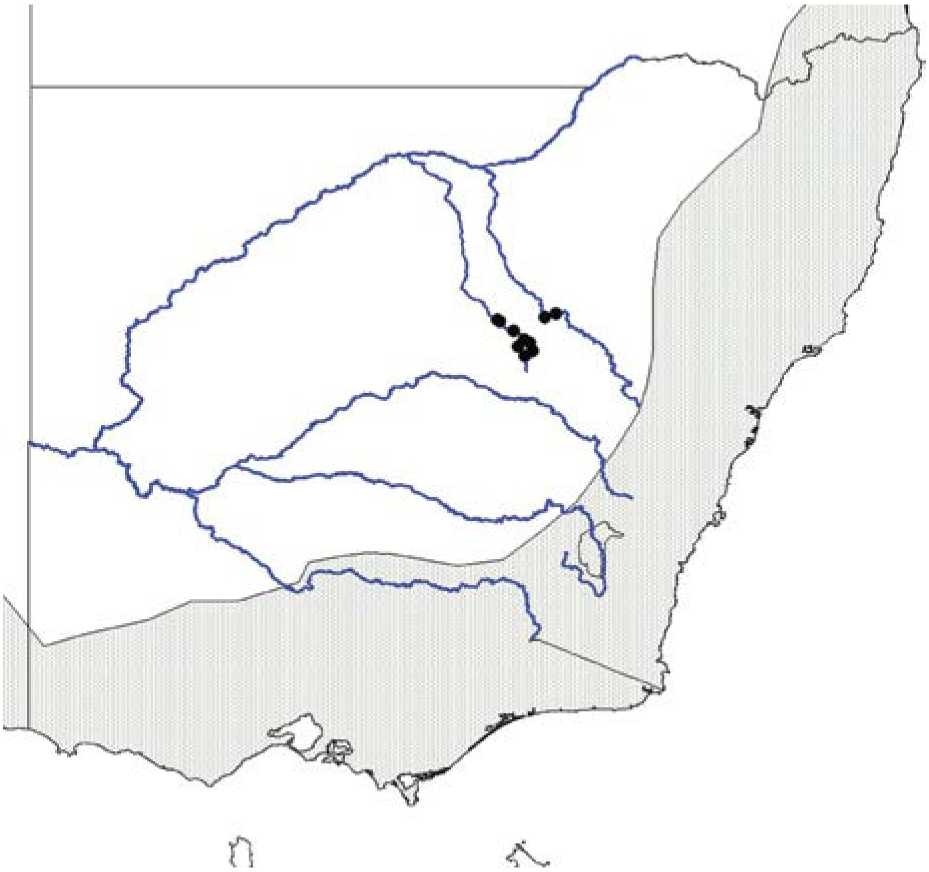

Figure 3. Large Forest Bat, *Vespadelus darlingtoni*, records from on the Bogan and Macquarie Rivers, NSW (dot; present study) with the distribution from the 2008 Global Mammal Assessment by the IUCN (shaded).

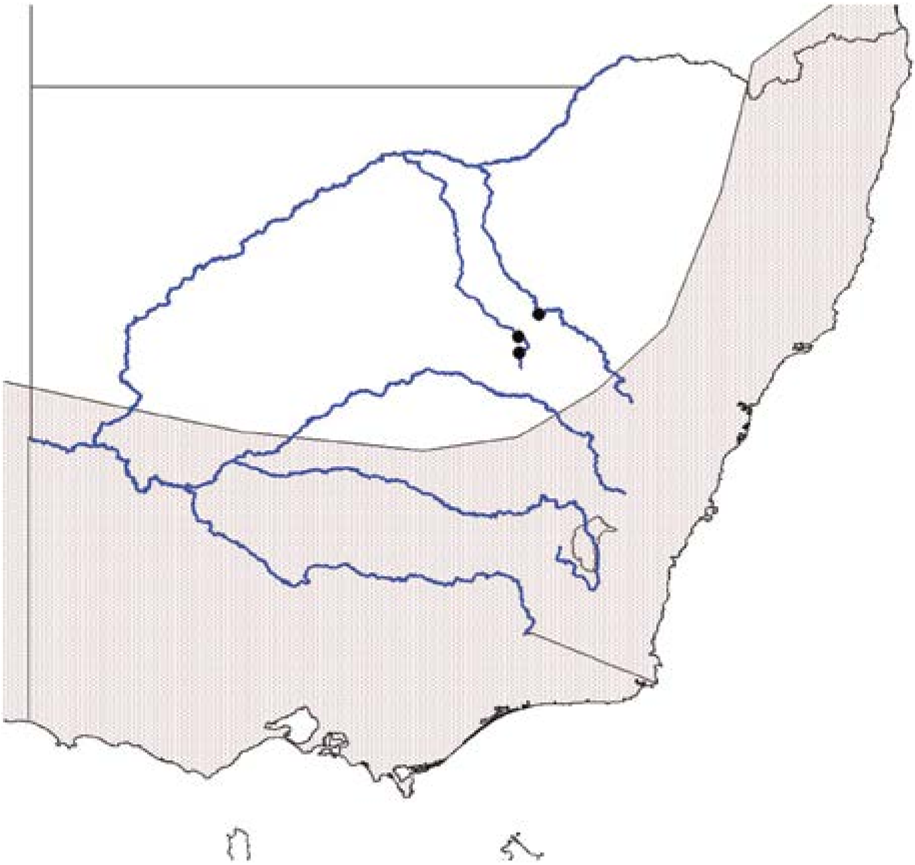

Figure 4. Southern Forest Bat, *Vespadelus regulus,* records on the Bogan and Macquarie Rivers, NSW (dots; present study) with the distribution from the 2008 Global Mammal Assessment by the IUCN shaded.

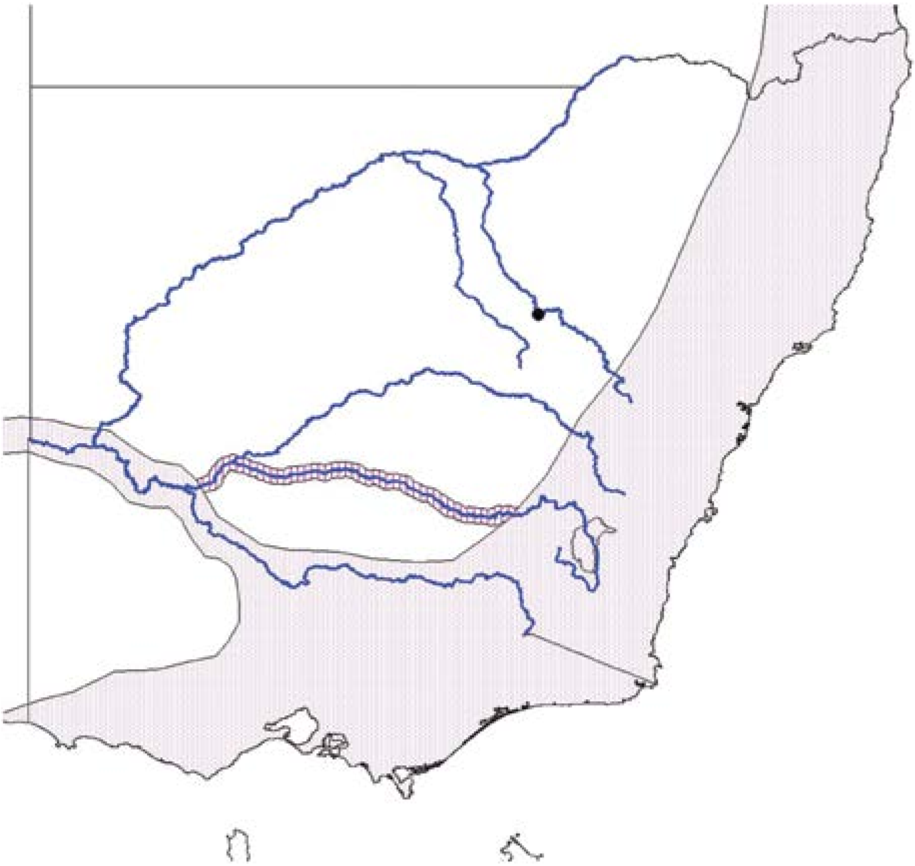

Figure 5. Large-footed Myotis, *Myotis macropus*, records on the Macquarie River, NSW (dots; present study) with the distribution from the 2008 Global Mammal Assessment by the IUCN shaded and the additional distribution by Churchill (2008) hatched.

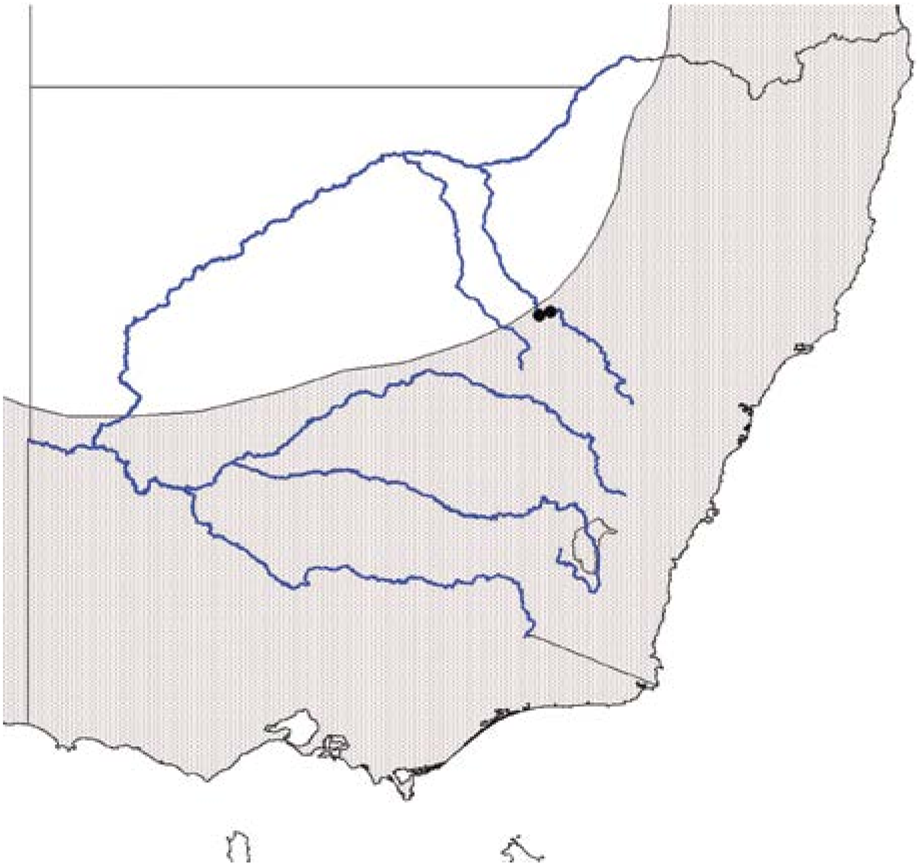

Figure 6. Chocolate Wattled Bat, *Chalinolobus morio*, records on the Macquarie River, NSW (dots; present study) with the distribution from the 2008 Global Mammal Assessment by the IUCN shaded.

riparian vegetation as corridors for movement through the landscape. Nevertheless, our data provide evidence of three species using riparian areas beyond their known ranges, and trapping is needed to confirm their presence in the study area and further inland.

If these species occur in the study area, are they a permanent part of the bat fauna of these rivers or do they move into the area following rainfall events? Following prolonged drought (2001 to 2009), the region had a period of high rainfall and flooding commencing February 2010 with high rainfall events continuing through until March 2012 with a corresponding increase in some bird populations (M.V. Ellis and J.E. Taylor, unpublished data). It is possible that bats were taking advantage of good conditions to move along water courses, however surveys during periods of drought are required to make such an assessment.

The diversity of bat fauna recorded in our study was similar to that recorded in *E. camuldulensis* vegetation elsewhere (Lumsden and Bennett 1995; Law and Anderson 1999). We did, however, record two species (*Saccolaimus flaviventris* Peters and *Scotorepens greyii* Gray) that were not recorded along the Murray River by Law and Anderson (1999) or Lumsden and Bennett (1995). However, both species have been detected in low to moderate densities in semi-arid NSW (Pennay *et al.* 2011).

We had relatively few records of *Myotis macropus*, *C. morio* Gray and *C. picatus* in our surveys. *Myotis macropus* may be rare in our study area as it is in other inland areas (Law and Anderson 1999). *Chalinolobus morio* has a scattering of populations across inland Australia but the majority of its distribution can be described as Bassian (Churchill 2008; Pennay *et al.* 2011) and our records fit with Churchill's (2008) statement that this species' inland distribution tends to follow water courses. However, we did not survey adjacent plains vegetation in this study and *C. morio* has also been recorded in mallee vegetation away from the course of the Murray River (Mazzer *et al.* 1998).

The two forest bats, *V. darlingtoni* and *V. regulus* Thomas, are reported from sclerophyll forests of the Great Dividing Range (Churchill 2008; Hoye *et al.* 2008; Tidemann *et al.* 2008) but our records are west of their previously described NSW distribution (Pennay *et al.* 2011). *Vespadelus regulus* also occurs along the Murray River and throughout western Victoria (Churchill 2008; Tidemann *et al.* 2008) while *V. darlingtoni* has also been recorded at the mouth of the Murray River near Lake Alexandrina, South Australia and along the river near Deniliquin, NSW (Law and Anderson 1999).

In conclusion, riparian vegetation in the semi-arid woodlands of the wheat-sheep belt of central-western NSW supports a diverse bat fauna, including three threatened species. Our study has identified potential extensions to the geographical range of three species, highlighting the need for further research in these poorly studied inland areas to provide further important baseline data about the bat fauna that they support.

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References

Adams, M. D., Law, B. S., and Gibson, M. S. 2010. Reliable automation of bat call identification for eastern New South Wales, Australia, using classification trees and AnaScheme software. *Acta Chiropterologica* **12:** 231-245. doi: http://dx.doi.org/10.3161/150811010X504725

Bedward, M., Simpson, C. C., Ellis, M. V., and Metcalfe L. M. 2007. Patterns and determinants of historical woodland clearing in central-western New South Wales, Australia. *Geographical Research* **45:** 348-357. http://dx.doi.org/10.1111/j.1745-5871.2007.00474.x

Bennett, A. F., Lumsden, L. F., and Nicholls, A. O. 1994. Tree hollows as a resource for wildlife in remnant woodlands: spatial and temporal patterns across the northern plains of Victoria, Australia. *Pacific Conservation Biology* **1**: 222-235.

Brigham, R. M., and Fenton, M. B. 1991. Convergence in foraging strategies by two morphologically and phylogenetically distinct nocturnal aerial insectivores. *Journal of Zoology* **223**: 475-489. http://dx.doi.org/10.1111/j.1469-7998.1991.tb04778.x

Catterall, C.P., Piper, S.D., Bunn, S.E., and Arthur, J.M. 2001. Flora and fauna assemblages vary with local topography in a subtropical eucalypt forest. *Austral Ecology* **26**: 56–69. http://dx.doi.org/10.1111/j.1442-9993.2001.01074.pp.x

Churchill S. 2008. *Australian Bats*, 2nd edn. Jacana Books, Crows Nest, NSW.

Ellis, M.V., and Taylor, J. E. 2013. Birds in remnant woodland vegetation in the central wheatbelt of New South Wales during the drought years 2005 to 2009. *Australian Zoologist* **36:** 332-348. http://dx.doi.org/10.7882/AZ.2012.019

Ellis, M.V., Williams, C.R., and Wilson, P. 1989. Extension to the known range of Gould's Long-eared bat *Nyctophilus gouldi* Tomes, 1858 (Chiroptera: Vespertilionidae) in New South Wales. *Australian Zoologist* **25:** 79-82.

Estrada, A., Jiménez, C., Rivera, A., and Fuentes, E. 2004. General bat activity measured with an ultrasound detector in a fragmented tropical landscape in Los Tuxtlas, Mexico. *Animal Biodiversity and Conservation* **2**: 1-9.

Fukui, D.A.I., Murakami, M., Nakano, S., and Aoi, T. 2006. Effect of emergent aquatic insects on bat foraging in a riparian forest. *Journal of Animal Ecology* **75**: 1252-1258. http://dx.doi.org/10.1111/j.1365-2656.2006.01146.x

Gonsalves, L., Law, B., Webb., C., and Monamy, V. 2012. Are vegetation interfaces important to foraging insectivorous bats in endangered coastal saltmarsh on the central coast of New South Wales? *Pacific Conservation Biology* **18**: 282-292.

Grindal, S. D., Morissette, J. L., and Brigham, R. M. 1999. Concentration of bat activity in riparian habitats over an elevational gradient. *Canadian Journal of Zoology* **77**: 972-977. http://dx.doi.org/10.1139/z99-062

Hoye, G. A., Herr, A., and Law, B. S. 2008. Large Forest Bat, *Vespadelus darlingtoni*. *The Mammals of Australia* (Eds S. van Dyck and R. Strahan). Reed New Holland, Sydney, pp. 562-563.

Law, B., and Anderson, J. 1999. A survey for the Southern Myotis *Myotis macropus* (Vespertilionidae) and other bat species in River Red Gum *Eucalyptus camaldulensis* forests of the Murray River, New South Wales. *Australian Zoologist* **31**: 166-174.

Law, B., Chidel, M., and Tap, P. 2011. Bat activity in ephemeral stream-beds in the Pilliga forests: clarifying the importance of flyways and buffer widths in open forest and woodland. In: *The Biology and Conservation of Australasian Bats* (eds B. Law, P. Eby, D. Lunney and L. Lumsden) pp. 308-321. Royal Zoological Society of NSW: Sydney. http://dx.doi.org/10.7882/FS.2011.031

Limpens, H.J.G.A., and Kapteyn, K. 1991. Bats, their behaviour and linear landscape elements. *Myotis* **29**: 63-71.

Lookingbill, T.R., Elmore, A.J., Engelhardt, K.A.M., Churchill, J.B., Gates, J.E., and Johnson, J.B. 2010. Influence of wetland networks on bat activity in mixed-use landscapes. *Biological Conservation* **143**: 974-983. http://dx.doi.org/10.1016/j.biocon.2010.01.011

Lumsden, L. F., and Bennett, A. F. 1995. Bats of a semi-arid environment in south-eastern Australia: biogeography, ecology and conservation. *Wildlife Research* **22**: 217-240. http://dx.doi.org/10.1071/WR9950217

Lumsden, L. F., Bennett, A. F., and Silins, J. E. 2002. Selection of roost sites by the lesser long-eared bat (*Nyctophilus geoffroyi*) and Gould's wattled bat (*Chalinolobus gouldii*) in south-eastern Australia. *Journal of Zoology* **257**: 207-218. http://dx.doi.org/10.1017/S095283690200081X

Mac Nally, R., Soderquist, T. R., and Tzaros, C. 2000. The conservation value of mesic gullies in dry forest landscapes: avian assemblages in the box-ironbark ecosystem of southern Australia. *Biological Conservation,* **93:** 293-302. http://dx.doi.org/10.1016/S0006-3207(99)00154-8

Martin, T.G., McIntyre, S., Catterall, C.P., and Possingham, H.P. 2006. Is landscape context important for riparian conservation? Birds in grassy woodland. *Biological Conservation* **127:** 201-214. http://dx.doi.org/10.1016/j.biocon.2005.08.014

Mazzer, T., Ellis, M., Smith, J., Ayers, D., Cooper, M., Wallace, G., and Langdon, A. 1998. *The Fauna of Western New South Wales: the Southern Mallee Region*. (NSWNPWS, Hurstville).

Metcalfe L., Sivertsen D. P., Tindall D., and Ryan K. M. 2003. Natural vegetation of the New South Wales wheat-belt (Cobar-Nyngan-Gilgandra, Nymagee-Narromine-Dubbo 1:250 000 vegetation sheets). *Cunninghamia* **8**: 253-284.

Monadjem, A., and Reside, A. 2008. The influence of riparian vegetation on the distribution and abundance of bats in an African savanna. *Acta Chiropterologica* **10**: 339-348. http://dx.doi.org/10.3161/150811008X414917

Pennay, M., Law, B., and Lunney, D. 2011. Review of the distribution and status of the bat fauna of New South Wales and the Australian Capital Territory. In: *The Biology and Conservation of Australasian Bats* (eds B. Law, P. Eby, D. Lunney and L. Lumsden) pp. 226-256. Royal Zoological Society of NSW: Sydney. http://dx.doi.org/10.7882/FS.2011.025

Pennay, M., Law, B., and Reinhold, L. 2004. Bat calls of New South Wales: region based guide to the echolocation calls of microchiropteran bats. NSW Department of Environment and Conservation, Hurstville.

Rayner, R., Ellis, M., and Taylor, J.E. 2011. Double sampling to assess the accuracy of ground-based surveys of tree hollows in eucalypt woodlands. *Austral Ecology* **36:** 252-260. http://dx.doi.org/10.1111/j.1442-9993.2010.02145.x

Rayner, L., Ellis, M.V., and Taylor, J.E. (in press). Hollow occurrence and abundance varies with tree characteristics and among species in temperate woodland *Eucalyptus*. *Austral Ecology* DOI: 10.1111/aec.12052

Sivertsen D. P. 1993. Conservation of remnant vegetation in the box and ironbark lands of New South Wales. *Victorian Naturalist* **110**: 24-29.

Skalak, S.L., Sherwin, R.E., and Brigham, R.M. 2012. Sampling period, size and duration influence measures of bat species richness from acoustic surveys. *Methods in Ecology and Evolution* **3**: 490-502. http://dx.doi.org/10.1111/j.2041-210X.2011.00177.x

Spencer, W. B. (1896). *Report on the Work of the Horn Scientific Expedition to Central Australia*. Dulau and Co., London. Summary, p.197

Tidemann, C. R., and Law, B. S. 2008. Southern Forest Bat, *Vespadelus regulus*. *The Mammals of Australia* (Eds S. van Dyck and R. Strahan). Reed New Holland, Sydney, pp. 569-570.

van Dyck, S., and Strahan, R. 2008. *The Mammals of Australia*. New Holland Publishers, Sydney.

Verboom, B. and Huitema, H. 1997. The importance of linear landscape elements for the pipistrelle *Pipistrellus pipistrellus* and the serotine bat *Eptesicus serotinus*. *Landscape Ecology* **12**: 117-125. http://dx.doi.org/10.1007/BF02698211

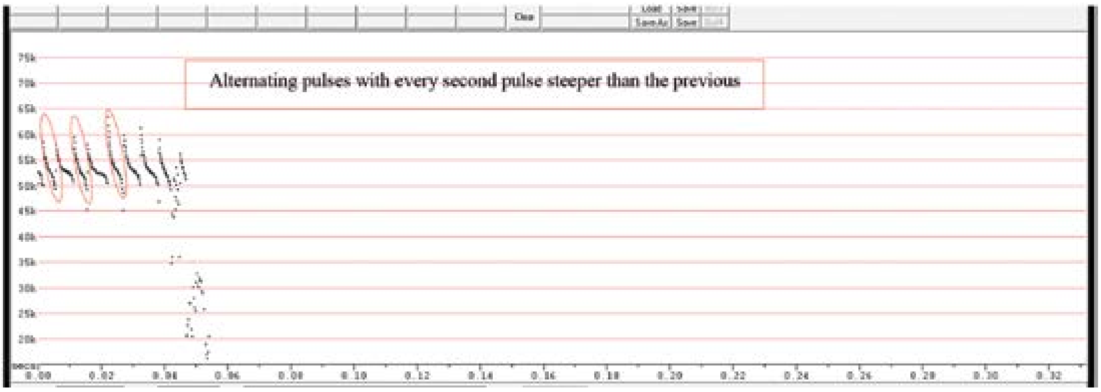
Whitaker, D.M., Carroll, A.L., and Montevecchi, W.A. 2000. Elevated numbers of flying insects and insectivorous birds in riparian buffer strips. *Canadian Journal of Zoology* **78**: 740-747. http://dx.doi.org/10.1139/cjz-78-5-740

Williams, S. 1994. The importance of riparian habitats to vertebrate assemblages in North Queensland woodlands. *Memoirs of the Queensland Museum* **35**: 248.

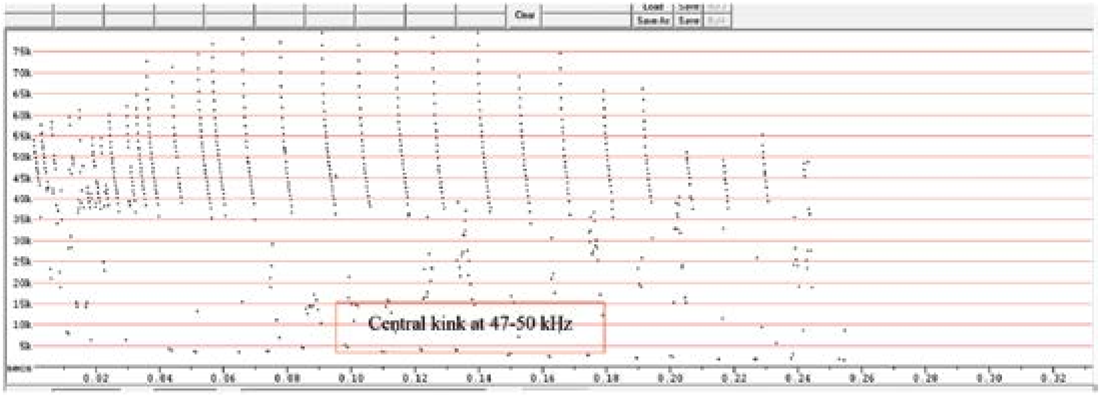
Young, R. A., and Ford, G. I. 2000. Bat fauna of a semi-arid environment in central western Queensland, Australia. *Wildlife Research* **27:** 203-215. http://dx.doi.org/10.1071/WR98071

APPENDIX I

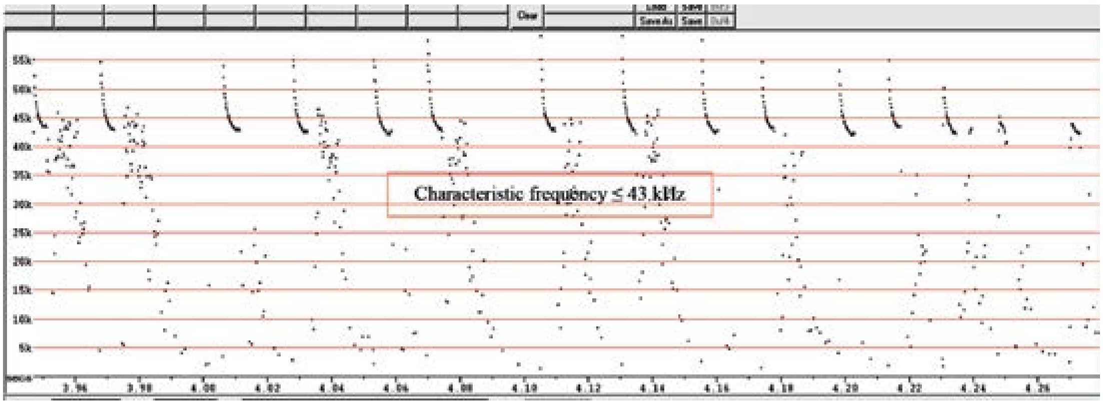
Example calls of four microchiropteran species with a predominantly Bassian coastal range detected in semi-arid New South Wales (December 2012-March 2013).



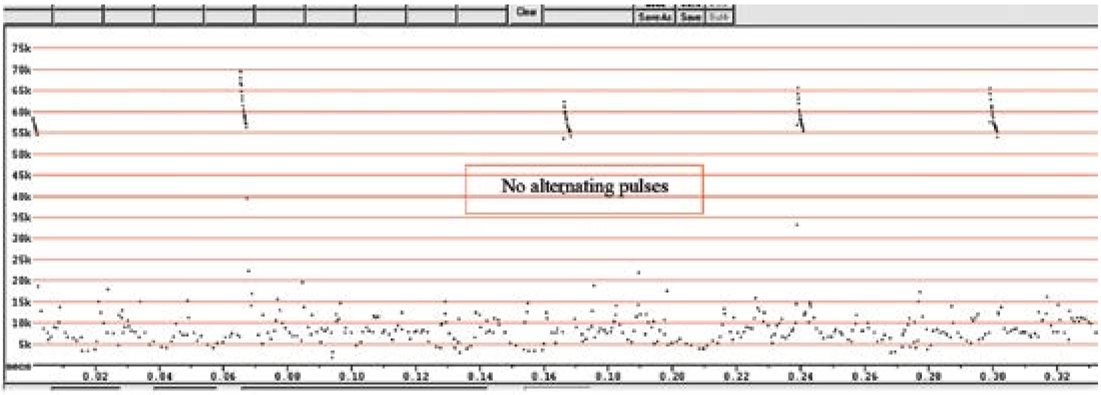
Anabat file identified as *Chalinolobus morio*



Anabat file identified as *Myotis macropus*



Anabat file identified as *Vespadelus darlingtoni*



Anabat file identified as *Vespadelus regulus*